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One-way Delay Measurement Based on Deterministic Networking

Abstract

One-way delay is a key indicator to measure network quality. Some
applications are one-way transmission in the network, such as some
high-definition video services, and are very sensitive to one-way
delay. Excessive delay will affect user experience greatly. To some
extent, the network can't even be used, so it is very important to
accurately measure the network transmission delay. The current one-
way delay measurement method has problems such as high complexity
and low measurement accuracy. In order to solve the problem of high-
precision one-way delay measurement, a one-way delay measurement
method based on deterministic networking is proposed in this
document. The method takes advantage of the delay characteristics of
the deterministic networking and does not depend on precise time
synchronization.The method realizes the one-way delay measurement of
any service flow between any network elements. Its technical
advantages are: the network does not need to send measurement
packets, can test all traffic types, does not change network status,
does not change the format of traffic packets, and does not require
network elements to support time synchronization protocols.

Status of This Memo

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1. Introduction

   One-way transmission delay is a key indicator to measure network
   quality. Some applications are based on one-way transmission in the
   network, such as some high-definition video services, and are very
   sensitive to one-way delay. Excessive one-way delay will affect user
   experience dramatically, so it is very important to accurately
   measure the one-way transmission delay of the network.

   There are several kinds of methods to measure one-way delay. The
   first kind of methods is active measurement. A sender will send
   measurement protocol messages, such as Two-Way Active Measurement
   Protocol (TWAMP) [RFC8186]messages, to the network to measure the
   one-way delay of the sender and receiver. The advantage of active
   measurement is that it is flexible in application. The disadvantage
   is that the measurement messages cannot measure the delay of real
   services, and the measurement of one-way delay requires sender and
   receiver to support time synchronization protocol, such as NTP
   [RFC5905]and PTP [IEEE.1588.2008]. The first kind of methods is
   passive measurement. The passive measurement devices will calculate

network delay by collecting actual business traffic. The advantage
of passive measurement is that it can measure the one-way delay of
real services. The disadvantage is that two passive measurement
devices need to be deployed, and the two devices require time
synchronization, which is difficult to implement. The third kind of
methods is hybrid measurement. Hybrid measurement is a combination
of active and passive measurements, that is, inserting some fields
or flags in the service message to realize the delay measurement of
the actual service. The disadvantage is that the message format of
the actual service is changed, which will affect the forwarding
behavior of the service and have observer effect. The network
element needs to be able to recognize and forward the modified
service message, and time synchronization of the network element is
also required.

The above-mentioned one-way delay measurement methods have the
following shortcomings. Firstly, if the measurement message is
injected into actual network, it will occupy network bandwidth
resources and interfere with the actual service flow, so the
measured delay is not the delay of the actual service. Secondly, the
measurement equipment or network elements need to support time
synchronization protocols, which is difficult to implement and
costly.

To address the following shortcomings of existing methods, this
document presents the following technical solution. A high-precision
one-way delay measurement method is proposed, which can be used to
measure the one-way delay of actual service packets, without sending
measurement messages, without changing the actual network status,
without changing service messages, and without the need for network
elements to support time synchronization protocols.

2. Conventions Used in This Document

2.1. Terminology

   NTP Network Time Protocol

   PTP Precision Time Protocol

   TWAMP Two-Way Active Measurement Protocol

   SLA Service Level Agreement

2.2. Requirements Language

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and
   "OPTIONAL" in this document are to be interpreted as described in

BCP 14[RFC2119][RFC8174] when, and only when, they appear in all
capitals, as shown here.

3. One-way Delay Measurement Method Based on Deterministic Networking

```
+-------------------------------------------------------------+
|                   Centralized Control Node                  |
+----+------------+--------------+---------+---------+----+----+
     ^            ^              ^         ^         ^
     |            |          T4 |     T3 |         | Tn
     |            |             |     +----+----+   |
     |            |             |     | Network |   |
  T1 |        T2 | +---------------->Element 3+-+  |
     |            | |           |     |       | | |  |
     |            | |           |     +---------+ | |  |
     |            | |           |               | |  |
     |            | |           |               | |  |
     |            | |           |               | |  |
     |            | |           |               | |  |
+----+----+  +----+--+-+   +----+----+       +-v--+----+
| Network |  | Network |   | Network |       | Network |
|Element 1+--->Element 2+----->Element 4+--------->Element n|
|         |  |         |   |         |       |         |
+---------+  +---------+   +---------+       +---------+
```
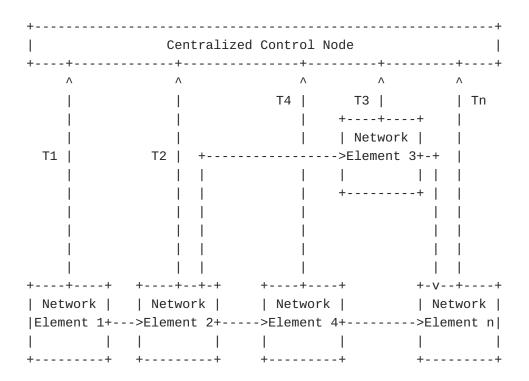
Figure 1: Figure 1: A schematic diagram of the network topology
                           structure

A schematic diagram of the network topology structure to describe
the proposed method is shown in Figure 1. The network may be a SDN
(Software Defined Network) or a traditional network. Whether it is
SDN or traditional network, there is a centralized control node (or
called a centralized management unit) for collecting network
information sent by network elements and sending control information
to the network. Taking SDN as an example, the centralized control
node can be a SDN controller. For traditional networks, the
centralized control node can be a network management system. The
information from the network element to the centralized control node
generally passes through the management network. In our solution,
the management network from each network element to the centralized
control node is required to use a delay deterministic network. As an
example, the delay deterministic network may be a time sensitive
network (TSN) or a deterministic Internet (Deterministic Internet
Network, DIP) [RFC8655], etc. Through the delay deterministic
network, the transmission delay of the network element information
from the network element to the centralized control node can be
guaranteed to be fixed. T1~Tn in Figure 1 represent the network

element information delay from the network element to the centralized control node of network element 1 to n respectively.

As shown in Figure 1, suppose network traffic of a real service flow passes through network element 1, network element 2, ..., network element n in turn, and the time when network traffic passes through the network element is recorded as t1, t2, ..., tn. The timestamp maybe the ingress timestamp of network traffic entering the network element or the egress timestamp of network traffic flowing out of the network element after the forwarding is completed. Each network element transmits the flow information to the centralized control node through the delay deterministic network when real traffic passes, and the transmission delays of each network element to transmit the flow information to the centralized control node through the delay deterministic network are denoted as T1, T2, ..., Tn, respectively. The timestamps when the centralized control node receives the flow information of each network element are t1', t2', ..., tn'.

Taking the calculation of the one-way transmission delay of traffic from network element 1 to network element 2 as an example, the one-way transmission delay can be calculated in the following way. Firstly, because the clocks of network element 1 and network element 2 are not synchronized, suppose the time deviation between the two is delta_t. Then the one-way transmission delay of traffic from network element 1 to network element 2 satisfies the following formula (1). Among them, Delay represents the one-way transmission delay of traffic from network element 1 to network element 2.

Formula (1): Delay = t2 - t1 - delta_t

Secondly, because the clocks between network element 1 and the centralized control node are not synchronized, assuming that the time deviation between the two is delta_t', the time for the traffic information collected from the network element 1 to reach the centralized control node through the delay deterministic network satisfies the following formula (2).

Formula (2): t1' = t1 + T1 + delta_t'

Thirdly, the clocks between network element 2 and the centralized control node are not synchronized, and the time deviation between network element 2 and the centralized control node is delta_t'-delta_t. The time t2' for the collected traffic to reach the centralized control node satisfies the following formula (3).

Formula (3): t2' = t2 + T2 + delta_t' - delta_t

Forthly, subtracting the formula (2) from the above formula (3), we can obtain the following formula (4).

Formula (4): t2 - t1 - delta_t = t2' - t1' + T1 - T2

Fifthly, substituting the above formula (4) into the above formula (1), the following formula (5) can be obtained.

Formula (5): Delay = t2' - t1' + T1 - T2

So far, the one-way transmission delay of traffic from network element 1 to network element 2 is obtained. Taking the calculation of one-way transmission delay of traffic from network element 1 to network element 3 as an example, the one-way transmission delay can be calculated in the following way: I) Referring to the above formula (5), the one-way transmission delay of traffic from network element 1 to network element 2 is: Delay12 = t2' - t1' + T1 - T2. II) Referring to the above formula (5), the one-way transmission delay of traffic from network element 2 to network element 3 is: Delay23 = t3' - t2' + T2 - T3. III) The one-way transmission delay of traffic from network element 1 to network element 3 is: Delay13 = Delay12 + Delay23 = t2' - t1' + T1 - T2 + t3' -t2' +T2 - T3 = t3' - t1' + T1 - T3. It can be seen that the one-way transmission delay between any two network elements can be calculated similarly to the above formula (5). For example, taking network element m and network element n as an example, the transmission delay of traffic from network element m to network element n is: Delay = tn' - tm' + Tm - Tn, where tn' and tm' are the time when the traffic information of network element m and network n reaches the centralized control node, and Tm and Tn are transmission delay of the traffic information from network element m and network element n to the centralized control node respectively through delay deterministic network.

4. **Procedures of the One-way Delay Measurement Method**

In this section, the procedures of the proposed one-way delay measurement method will be elaborated. Assume there are two network element. It is determined that the time when the centralized control node receives the first flow information is the first time, and the time when the second flow information is received by the centralized control node is determined to be the second time. The first flow information is sent to the centralized control node via delay deterministic network, and the second flow information is also sent to the centralized control node via delay deterministic network. The procedures of the one-way delay measurement method is shown in Figure 2.

```
+-----------+  +-----------+ +--------------------+ +-------------+
|  Network  |  |  Network  | | Delay Deterministic | | Centralized |
| Element m |  | Element n | |      Network        | | Control Node |
+-----+-----+  +-----+-----+ +--------------------+ +-------+------+
      |              |                                       |
      |              |                                       |
      |              |                                       |
      |              |       The first transmission    +-------+--------+
      |              |           delay is Tm           | tm' represents |
      +---------------------------------------------------> the first time |
      |              |                                 +-------+--------+
      |              |                                       |
      |              |                                       |
      |              |       The second transmission   +-------+--------+
      |              |           delay is Tn           | tn' represents |
      |              +------------------------------> the second time|
      |              |                                 +-------+--------+
      |              |                                       |
      |              |                                       |
      |              |                                       |
      +              +                                       +
```

   Figure 2: Figure 2: Procedures of the one-way delay measurement method

   The transmission delay of traffic from the first network element to
   the second network element can be determined based on the first
   time, the second time, the first transmission delay, and the second
   transmission delay.

   The first traffic information is sent by the first network element
   to the centralized control node via a delay deterministic network at
   the moment when the traffic passes through the first network
   element. And the time when the traffic passes through the first
   network element refers to the moment when traffic enters the first
   network element or the time when traffic flows out of the first
   network element.

   The second traffic information is sent by the second network element
   to the centralized control node via a delay deterministic network at
   the moment when the traffic passes through the second network
   element. And the time when the traffic passes through the second
   network element refers to the moment when traffic enters the second
   network element or the time when traffic flows out of the second
   network element.

   It is determined that the transmission delay of the first traffic
   information from the first network element to the centralized
   control node is the first transmission delay, and it is determined
   that the transmission delay of the second traffic information from

the second network element to the centralized control node is the second transmission delay. The transmission delay of traffic from the first network element to the second network element can be determined based on the following formula: Delay=tn'-tm'+Tm-Tn. Wherein, tn' represents the second time, tm' represents the first time, Tm represents the first transmission delay, Tn represents the second transmission delay, and Delay represents transmission delay of the traffic from the first network element to the second network element. In the above method, the delay deterministic network is used to ensure that the first transmission delay and the second transmission delay are fixed delays.

5. Security Considerations

TBD.

6. IANA Considerations

TBD.

7. Normative References

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